

CLAIMS

[1] In an electric motor control apparatus for a multiphase AC electric motor, including motor rotational angle detection means for calculating a rotational angle of the electric motor, a current detection circuit which calculates currents flowing through respective phases of the electric motor, current control means for determining multiphase voltage commands in accordance with a target q-axis current corresponding to a target value of a torque to be generated by the electric motor, and the detection currents of respective phases and the motor rotational angle from the current detection circuit and the motor rotational angle detection means, a switching-element drive circuit which subjects the multiphase voltage commands from the current control means, to PWM modulation, and which gives commands of switching operations to an inverter, and the inverter which receives switching operation signals from the switching-element drive circuit, and which applies voltages to the respective phases of the electric motor and causes currents to flow therethrough;

an electric motor control apparatus characterized in that the current control means comprises normal-mode current control means for use in a normal mode, abnormal-mode current control means for use in an abnormal mode, abnormality decision means for detecting an abnormal state of the electric motor

or the inverter, and changeover means for selecting either the normal-mode current control means or the abnormal-mode current control means on the basis of a command from the abnormality decision means, wherein in case of occurring abnormality to one phase of the electric motor or the inverter, the abnormal-mode current control means is selected by the changeover means, and abnormal-mode multiphase voltage commands generated by the abnormal-mode current control means are set as the multiphase voltage commands for the switching-element drive circuit.

[2] An electric motor control apparatus as claimed in claim 1, characterized in that the abnormal-mode current control means generates the voltage commands of the respective phases so as to satisfy a balanced condition in which a sum of the voltage commands of the normal phases except the phase undergoing the abnormality becomes zero, thereby to output the generated voltage commands as the abnormal-mode multiphase voltage commands.

[3] An electric motor control apparatus as claimed in claim 1, characterized in that the abnormal-mode current control means includes:

target phase current waveshaping means for calculating target currents of the respective phases in accordance with the target q-axis current corresponding to the target value of the motor torque, and the motor rotational angle, so as to

satisfy a balanced condition in which a sum of the target currents of the normal phases except the phase undergoing the abnormality becomes zero, and for outputting the calculated target currents as multiphase target currents; and

controllers which generate the abnormal-mode multiphase voltage commands on the basis of the target currents of the normal phases, and the detection currents of the respective phases from the current detection circuit;

wherein the target currents of the respective phases are individually designated by the target phase current waveshaping means, thereby to individually control currents of the respective phases of the electric motor.

[4] An electric motor control apparatus as claimed in claim 1, characterized in that the abnormal-mode current control means includes target phase current waveshaping means for generating a target current of a first phase in accordance with the target q-axis current corresponding to the target value of the motor torque, and the motor rotational angle, one controller which outputs a voltage command of the first phase on the basis of the target current of the first phase and the detection current from the current detection circuit, and conversion means for converting the voltage command of the first phase from the controller, into a voltage command opposite in sign and equal in absolute value, so as to output the resulting voltage command as a voltage command of a second

phase, wherein the voltage command of the first phase and the voltage command of the second phase are outputted as the multiphase voltage commands, thereby to control the three-phase AC electric motor.

[5] An electric motor control apparatus as claimed in claim 1, characterized in that the abnormal-mode current control means includes:

target phase current waveshaping means for calculating target currents of the respective phases in accordance with the target q-axial current corresponding to the target value of the motor torque, and the motor rotational angle, so as to satisfy a balanced condition in which a sum of the target currents of the normal phases except the phase undergoing the abnormality becomes zero, and for outputting the calculated target currents as multiphase target currents;

two-phase conversion means for subjecting the multiphase target currents to two-phase conversion on the basis of the motor rotational angle, thereby to generate a waveshaped d-axial target current and a waveshaped q-axial target current; and

dq control means for executing a dq control on the basis of the waveshaped d-axial target current and the waveshaped q-axial target current from the two-phase conversion means, the detection currents of the respective phases from the current detection circuit, and the motor rotational angle and

generating the multiphase voltage commands;

wherein the target currents of the respective phases are individually designated by the target phase current waveshaping means, so as to execute the dq control in which the waveshaped d-axial target current and the waveshaped q-axial target current are target signals of a d-axial current and a q-axial current, with the dq control means.

[6] An electric motor control apparatus as claimed in claim 1, characterized in that the abnormal-mode current control means includes:

dq control means for executing a dq control on the basis of the target q-axial current corresponding to the target value of the motor torque, the detection currents of the respective phases from the current detection circuit, and the motor rotational angle, and for generating voltage commands of the respective phases;

target phase current waveshaping means for calculating target currents of the respective phases in accordance with the target q-axial current corresponding to the target value of the motor torque, and the motor rotational angle, so as to satisfy a balanced condition in which a sum of the target currents of the normal phases except the phase undergoing the abnormality becomes zero, and for outputting the calculated target currents as multiphase target currents; and

voltage waveshaping means including two-phase

conversion means for subjecting the multiphase target currents to two-phase conversion on the basis of the motor rotational angle, thereby to generate a waveshaped d-axial target current and a waveshaped q-axial target current, and means for subtracting a target d-axial current and the target q-axial current from the waveshaped d-axial target current and the waveshaped q-axial target current, for generating a d-axial voltage command and a q-axial voltage command from the subtraction values, and for generating voltage waveshaping signals of the respective phases on the basis of the d-axial voltage command, the q-axial voltage command and the motor rotational angle;

wherein the multiphase voltage commands are outputted by adding the voltage commands of the respective phases from the dq control means and the voltage waveshaping signals of the respective phases from the voltage waveshaping means.

[7] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized in that the multiphase target currents which are generated by the target phase current waveshaping means of the abnormal-mode current control means are calculated in accordance with the target q-axial current corresponding to the target value of the motor torque, and the motor rotational angle, and that the calculated multiphase target currents are corrected depending upon a direction of the target q-axial current.

[8] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized in that the multiphase target currents which are generated by the target phase current waveshaping means of the abnormal-mode current control means are calculated in accordance with the target q-axial current corresponding to the target value of the motor torque, and an inverse number of a cosine concerning the motor rotational angle.

[9] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized in that the multiphase target currents which are generated by the target phase current waveshaping means of the abnormal-mode current control means are calculated in accordance with the target q-axial current corresponding to the target value of the motor torque, the motor rotational angle, and a motor rotational angular speed.

[10] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized in that the multiphase target currents which are generated by the target phase current waveshaping means of the abnormal-mode current control means are calculated in accordance with the target q-axial current corresponding to the target value of the motor torque, the motor rotational angle, a motor rotational angular speed, and a motor rotational angular acceleration.

[11] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized by comprising motor torque

detection means for calculating a torque which is to be generated by the electric motor, on the basis of the detection currents of the respective phases of the electric motor and the motor rotational angle, and for generating a motor torque signal, wherein the multiphase target currents which are generated by the target phase current waveshaping means of the abnormal-mode current control means are calculated in accordance with the target q-axis current corresponding to the target value of the motor torque, and the motor rotational angle, and the calculated multiphase target currents are corrected by the motor torque signal.

[12] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized in that the multiphase target currents which are generated by the target phase current waveshaping means of the abnormal-mode current control means have regions where the multiphase target currents are set at zero, in the vicinity of a motor rotational angle at which plus and minus signs of the multiphase target currents change.

[13] An electric motor control apparatus as claimed in any of claims 3 - 6, characterized in that the abnormal-mode current control means includes target dither current waveshaping means for generating an oscillatory signal in accordance with the target q-axis current corresponding to the target value of the motor torque, and the motor rotational angle, and for outputting the generated signal as a target dither current,

wherein the target dither current is superposed on the multiphase target currents outputted by the target phase current waveshaping means, so as to set new multiphase target currents.

[14] An electric motor control apparatus as claimed in claim 1, characterized in that the abnormal-mode current control means includes dq control means for executing a dq control on the basis of the target q-axial current corresponding to the target value of the motor torque, the detection currents of the respective phases from the current detection circuit, and the motor rotational angle, and for generating voltage commands of the respective phases, target dither current waveshaping means for generating an oscillatory signal in accordance with the target q-axial current and the motor rotational angle, and for outputting a target dither current of each phase, and target voltage conversion means for converting the target dither current into three-phase dither voltage commands, wherein the voltage commands of the respective phases outputted by the dq control means and the three-phase dither voltage commands outputted by the target voltage conversion means are added, so as to output the added voltage commands as the multiphase voltage commands.